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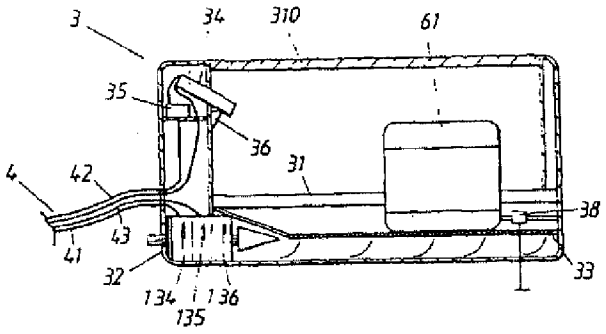

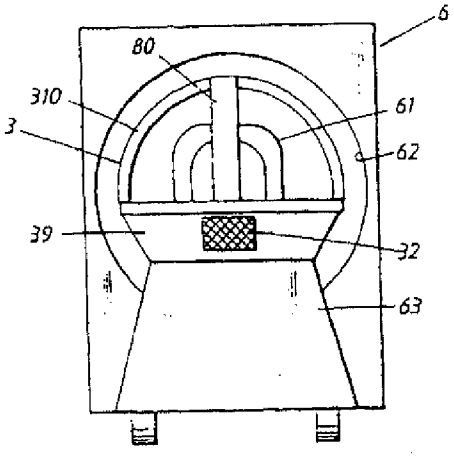

(57) Abstract: An incubator arrangement includes an incubator (3) having a child accommodating bed. The incubator (3) also includes a generally ring-shaped RF-coil (61) for a magnetic resonance imaging apparatus. The incubator (3) is dimensioned for insertion into a tunnel (62) in the imaging apparatus (6). The coil (61) and the bed (31) can be moved relative to one another in the longitudinal direction of the incubator (3), to enable the coil to surround the child at a selected longitudinal position therealong.

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INCUBATOR ARRANGEMENT FOR USE IN MAGNETIC RESONANCE IMAGING

The invention relates to an incubator arrangement intended for diagnosing thermounstable, newly born babies with the aid of magnetic resonance imaging and computer tomography.

Newly born babies who are considered to require care in incubators with adapted temperature levels and possibly also adapted atmospheric humidity levels may also need to be diagnosed with respect to deformities, malformations, illnesses, injuries, disorders, and like afflictions. Magnetic resonance imaging and computer tomography can be used beneficially for such diagnosis. The child is often required to lie in the MRT-scanner or CT-scanner for periods of up to one hour. In order to reliably diagnose the signs and symptoms of small babies, it is necessary for the babies to lie in an incubator in which a controlled temperature and humidity can be maintained in the child's environment whilst making the examination.

Accordingly, one object of the present invention is to provide an incubator arrangement in which the baby or child accommodating part can be located in a magnetic resonance technology apparatus and/or in a computer tomography apparatus with the child lying in the incubator part and while maintaining a suitable environment in the incubator, wherein breathing of the child can be supported, infusion solutions administered, and wherein the interior space of the incubator part can be video monitored.

This object is achieved with an incubator arrangement of the kind defined in the accompanying dependent Claims. Further embodiments of the inventive incubator arrangement are defined in the accompanying dependent Claims.

The inventive incubator arrangement is characterized in that it includes a MRT coil in addition to a child accommodating bed. The bed and the coil are preferably movable in relation to one another, such that the coil will surround the bed and be displaceable therealong. The MRT coil can thereby be placed in any desired longitudinal position relative to the child for MRT image examination of selected longitudinal sections of the child's body. The coil is also movable away from the child, so as to fully expose the child. This enables computer tomography to be carried out without being hindered or made difficult by the coil.

An examination carried out in a Magnetic Resonance Technology imaging apparatus means that a very strong magnetic field (about 1.5 Tesla) will be developed over a short period of time and in a limited space, thereby requiring the incubator to be constructed to withstand this effect. Naturally, that part of the incubator that is located in the MRT-apparatus or the Computer Tomography apparatus must be adapted to the conditions that prevail therein, in order to minimize the effect of interference on the pictures, or images, that one wishes to produce.

Particularly in the light of the time in which the child may need to lie in the magnetic resonance imaging apparatus or in the computed tomographic apparatus, that part of the incubator in which the child lies ("the incubator") must be supplied with energy that will enable the atmosphere in the incubator to be maintained at a selected controlled temperature level, and it is also necessary to recirculate the air in the incubator so as to equalize variations in the properties of the atmosphere in different parts of the incubator part. It is also beneficial to be able to video monitor the child, i.e. the incubator interior, and also to be able to read-off, e.g., temperatures in the incubator with the aid of a monitor that is distanced from the incubator. In

view of the magnetic field that prevails in a magnetic resonance imaging apparatus, it is suitable to equip the incubator with a converter that will convert received video signals and electric signals to optical signals that are conducted to a remotely located monitoring part of the incubator (the base unit) via light conductors that are conveniently interference filtered.

The incubator will preferably also include a heating source, which may have the form of resistive heating elements operated suitably with a d.c. voltage. The incubator will also conveniently include a fan that functions to transfer heat from the heating battery to the incubator atmosphere and that is driven by a secondary fluid turbine to which power is supplied with the aid of fluid taken from a remotely located part of the incubator arrangement (the base unit). A typical electric motor would not function correctly in the magnetic fields that are generated in the examining equipment.

The base unit may also contain air and oxygen tubes, oxymixers and respirators that are adapted for use in magnetic fields, wherein the tubes may, for instance, consist of a non-magnetic material. The remotely located base unit may also include one or more infusion pumps which function to supply fluid to the child via catheters pipes or like conducting means. The incubator also includes sensors which are connected to the base unit via conductors, for controlling or adjusting devices in the incubator or the flow thereto.

The incubator arrangement includes an incubator that is acoustically insulated in a manner to reduce the high sound levels that occur when carrying out examinations with the aid of magnetic resonance imaging apparatus (about 90 dB). Acoustic attenuation can be established by providing the

incubator with a double wall structure, at least in its transparent parts.

The incubator arrangement also includes a base unit that is connected to the incubator part via a bundle of conductors of the aforesaid kind. The magnetic X-ray coil has a connecting line that extends out of the incubator and that can be connected to a corresponding output on the magnetic resonance imaging apparatus, so as to forward the signals captured by the coil.

The base unit may contain a primary turbine for driving the heating fan and a battery for supplying energy to the heating element. The incubator is suitably constructed to enable it to be placed stably on the base unit/monitoring unit, which, in turn, is supported on a drivable carriage or simply on a carriage that can be transported by a transport vehicle. For instance, the carriage may be of a kind that can be collapsed in conjunction with ambulance transportation.

The incubator has a heating element and a fan which drives air past the heating element and through a humidifying unit. The incubator contains no water mass or other material that would be liable to interfere with magnetic resonance and computed topography examinations.

The invention will now be described in more detail with reference to an exemplifying embodiment thereof and also with reference to the accompanying drawings.

Fig. 1 is a vertical, central longitudinal sectional view of the inventive incubator.

Fig. 2 is an end view of the incubator.

Fig. 3 is a schematic view of the incubator arrangement placed in connection with a magnetic resonance imaging apparatus.

Fig. 4 is a partial section through the incubator and the RF-coil therein.

Fig. 5 is a section taken along V-V in Fig. 4.

As will be seen from Fig. 3, the inventive incubator arrangement includes a base unit 1 which is supported on a carrier/carriage 2 of conventional design for transportation purposes. The incubator arrangement also includes an incubator 3 which is connected to the base unit 1 via a flexible conductor bundle 4. The incubator 3 also includes an outgoing cable 5 for connection to a signal input of an image interpretation part of a magnetic resonance imaging apparatus 6 into which the incubator 3 can be moved for MR-imaging of a child placed in the incubator.

Referring now to Figs. 1 and 2, it will be seen that the incubator 3 has an upper transparent part 310 in the form of a generally semi-cylindrical shell that rests on a tray-like chassis structure 39. The incubator 3 (310, 39) has cross-sectional dimensions that are smaller than the tunnel opening 62 of an MRT-imaging apparatus 6 or the tunnel opening of a CT-scanner (not shown). The opening 62 will normally have a diameter of about 55 cm. The incubator has a diameter of about 40-45 cm and a total length of about 80 cm.

It will be seen form Figs. 1 and 2 that the incubator 3 includes a bed 31 on which the child is positioned in the longitudinal direction of the incubator.

A generally ring-shaped RF-coil is mounted inside the incubator 3. The coil 61 functions to capture the response of when the child is subjected briefly to a radio wave by the MR-imaging apparatus.

The coil 61 is intended to surround both the bed 31 and the child lying thereon. The coil 61 is shown resting on a path

33 in the form of a perforated supportive plate that is adapted to support the coil 61 stably in a selected position of displacement relative to the bed 31, in the longitudinal direction of the incubator 3. Also shown is a displacement means 38 for remote control of longitudinal movement of the coil 61 relative to the bed 31. The displacement means 38 may be driven with power and control signals delivered from the base unit 1 through the medium of suitable cables (not shown) included in the conductor bundle 4. In one preferred embodiment, the bed 31 is fixed in the incubator and the coil 61 is mounted for movement along the bed 31, wherewith the coil 61 surrounds the bed and the child lying thereon. will There will preferably be provided in the incubator at one short end of the bed, a space into which the coil 61 can be moved when the child on the bed shall be imaged in a CT-scanner, so that the coil 61 will not screen any part of the child.

The incubator 3 is also sound-proofed so as to minimize the effect of the noise generated by the MR-imaging apparatus (about 90 dB) on the child. The greater part of the upper portion 310 of the incubator will preferably be transparent, wherewith the light transparent part may be constructed of several generally parallel transparent walls that also provide heat insulation.

Heat can be supplied to the incubator 3 even when the heat supply means is subjected to the magnetic field of the MR-imaging apparatus. Accordingly, in one embodiment of the invention, the incubator is provided with a resistive heater that is operated with d.c. voltage from the base unit 1, for instance from a battery pack 11 therein. The atmosphere in the incubator 3 is circulated by means of a circulation fan 34 mounted in the incubator and preferably driven by an incubator-mounted secondary turbine which is driven by a fluid flow (air/water flow) that is circulated from the base

unit 1 via a flexible pipe 41. Also mounted in the incubator is an air humidifier 36 with which air introduced into the incubator is moisturized. Moisture can be supplied to the air humidifier by liquid conducted from the base unit through a pipe (not shown). Pipes (not shown) may also be connected between the base unit and the incubator for transferring oxygen and possibly other gases to the incubator, possibly to a breathing mask fitted on the child.

A video camera 34 is mounted in the incubator, suitably on a column 80 at one upper end-part of the incubator. The video camera output signal, and also any other signals that are to be transmitted from the incubator, e.g., to the base unit 1 may conveniently be converted by an opto-converter 35 whose output signals are sent to the base unit 41 via a screened light conductor 42. The optical signals can then be converted back to electric signals and therewith simplify further processing of the information. The bunch of conductors 4 may also include flexible lines for transferring infusion solutions from the base unit to the incubator 3 and to the child lying therein.

The base unit 1 has an upper side which is constructed to afford stable support to the incubator 3 in conjunction with transportation of the incubator arrangement, and the child lying in the incubator is also afforded a stable and controlled environment even during transportation and during examination in respect of MRT and CT diagnoses.

The inventive incubator can be used for the following purposes, for instance:

- Diagnosis of malformation in the central nervous system;
- Diagnosis of abdomen and thorax malformation;
- Diagnosis of hypoxic-ischemic brain damage;
- Diagnosis of neonatal strokes;

- Diagnosis of ischemic skull injury and bleeding in premature babies;
- Diagnosis of central respiratory disturbances;
- Diagnosis of heart anomalies; and
- Stereotactic surgery (fixation in the incubator).

It will be understood that other forms of diagnosis are possible with the inventive incubator arrangement.

Although not shown in detail, the dimensions of the incubator 3 are chosen to allow the incubator 3 to be received in the tunnel (not shown) of a conventional computed tomographic scanner.

The incubator 3 is also constructed to minimize impairment of the images taken in the MRT and CT examinations to the greatest possible extent, and the interior parts of the incubator are chosen to withstand those stresses and strains that occur with MRT and CT. The incubator 3 is suitably made of plastic or wood in that area in which imaging takes place. All forms of metal must be avoided in this area (i.e. everywhere with the exception of said short end in which the fan, heater and video camera are placed outside the imaging area).

Since, e.g., the incubator 3 cannot contain any liquid mass, such as heat layers and heat distributors, it is necessary to transfer heat directly from the base unit 1. Because a relatively large amount of heat will be lost when transferring heat via a hot fluid through a pipe that extends between the unit 1 and the incubator 3, and because a control inertia occurs between the heat source and the incubator, it is preferred to mount a direct current heater 35 inside the incubator and to supply direct current to the heater via a cable 43 in the conductor bundle 4. A fan is also required to circulate the atmosphere in the incubator 3 and to suck in

ambient air through an air intake fitted with a filter 32. The fan motor must be capable of withstanding the invironment of the imagning apparatus and is therefore driven entirely by a secondary turbine which, in turn, is supplied with energy through the medium of a fluid flow from the unit 1.

The perforations in the carrier plate 33 function to distribute the air flow from the fan uniformly through the interior of the incubator 3, and a filter opening (not shown) allows consumed air to leave the incubator 3.

The tranparent upper shell part 310 and the lower tray-shaped shell part 39 usually form a closed shell in which an atmospere of chosen composition can be upheld. Normally an atmosphere with increased oxygen proportion is maintained within the incubator. Usually there are also fluids and high humidity within the incubator. The RF-coil can be of the sending type, but is usually of the receiving type. For safety reasons, i.e. in order to prevent the RF-coil and the connection cable 5 to the coil from engagement with the atmosphere, the fluids and the humidity within the incubator, the coil 61 is enclosed in a cover 70. The cover 70 can be formed by impermeable sheet material such as a plastic foil and is preferably of an annular shape in order to still permit a child to be located within the coil. Moreover, a protective tube 71 is arranged to surround the cable 5 between the enclosure 70 and the incubator shell 39. The tubing 71 is preferably shaped in order to be enlongated and contracted, and can to this end be shaped as a folded bellows 75 along at least a part of the length thereof. The tube 71 is at an end 72 sealingly joined to the cover 70 in order to communicate with the inside of the cover 70. At the other end 74, the tube is sealingly joined to the incubator shell 39 around an opening therethrough. The inside of the cover 70 is in communication with the atmospere surrounding the incubator, via the tube 71. The tube 71 is arranged to permit the coil with cover to be displaced within the incubator. During this displacement, the cable 5 can be displaced through the tube and the shell opening 77 to which the second end 74 of the tube sealingly connects.

CLAIMS

1. An incubator arrangement comprising an incubator (3) having a child accommodating bed, **characterized** in that the incubator (3) includes a generally ring-shaped RF-coil (61) for a magnetic resonance imaging apparatus; and in that the incubator (3) is dimensioned for insertion into a tunnel (62) in the imaging apparatus (6).

2. An incubator arrangement according to Claim 1, **characterized** in that the incubator (3) is substantially X-ray transparent, with the exception of the coil (61), to enable the incubator and child to be subjected to computer tomography.

3. An incubator arrangement according to Claim 1 or 2, **characterized** in that the coil (61) is adapted to surround the bed (31) and the child lying thereon.

4. An incubator arrangement according to any one of Claims 1-3, **characterized** in that the coil (61) and the bed (31) are movable in the longitudinal direction of the incubator (3) in relation to one another, so as to enable the coil to surround the child at selected positions along the length of the child.

5. An incubator arrangement according to any one of Claims 1-4, **characterized** by bearing means (33) for supporting the coil (61) and guiding the coil in its longitudinal movement.

6. An incubator arrangement according to Claim 3 or 4, **characterized** by means (38) for remotely controlling movement of the coil (61) in the incubator (3).

7. An incubator arrangement according to Claim 1, **characterized** in that the incubator (3) and its inner part are chosen and constructed to minimize the effect of the magnetic pulses generated by the magnetic resonance imaging apparatus.

8. An incubator arrangement according to Claim 7, **characterized** in that the incubator and its inner parts are chosen and constructed to minimize the effect of the signal responses of the magnetic resonance imaging apparatus from the child and on CT-images of the child.

9. An incubator arrangement according to any one of Claims 1-4, **characterized** by a base unit (1) that is connected to the incubator by a flexible bundle of conductors (4) which function to transfer signals, power and fluid between the base unit (1) and the incubator (3).

10. An incubator arrangement according to Claim 9, **characterized** in that the upper side of the base unit (1) is constructed to provide stable heating of the incubator (3).

11. An incubator arrangement according to Claim 9 or 10, **characterized** in that the base unit (1) is carried on a transport carriage (2).

12. An incubator arrangement according to any one of Claims 1-3, **characterized** in that the coil (61) mounted in the incubator (3) is connected to a signal line (5) which extends out of the incubator and is connectable to the signal processing unit of the magnetic resonance imaging apparatus.

13. An incubator arrangement according to any one of Claims 1-3, **characterized** in that the incubator (3) has a light-transparent upper part (31) which is acoustically insulated

by virtue of at least two mutually adjacent transparent shell-like walls.

14. An incubator arrangement according to any one of Claims 9-11, **characterized** in that the base unit (1) includes a battery pack for supplying energy to a video camera and to a circulation fan in the incubator (3), means for regulating and monitoring the ECG and O_2 saturation of the child and the child's temperature, means for regulating the temperature of the incubator, respiratory treatment means and treatment means such as an injector pump.

15. An incubator arrangement according to any one of Claims 1-14, **characterized** in that the RF-coil (61) is enclosed in an impermeable annular cover (70) and in that the interior of the cover (70) is in communication with the atmosphere surrounding the incubator via a tube (71), and in that a signal cable (5) which is connected to the coil extends through the tube.

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Fig. 1

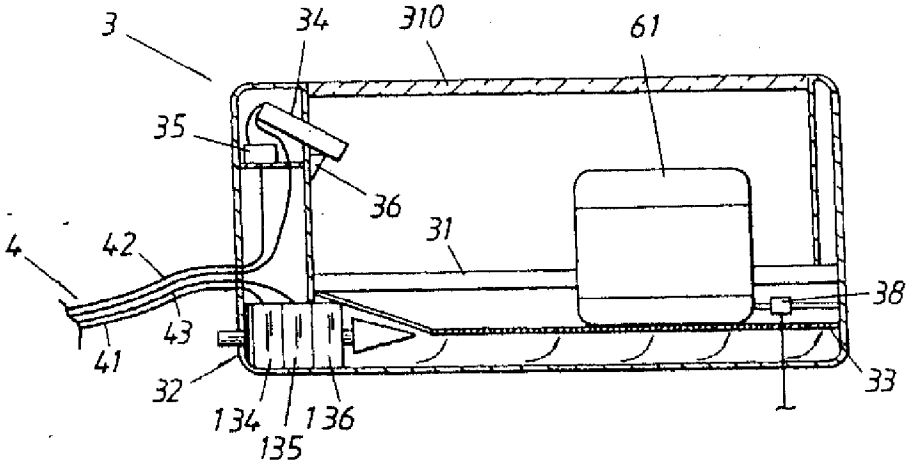

Fig. 2

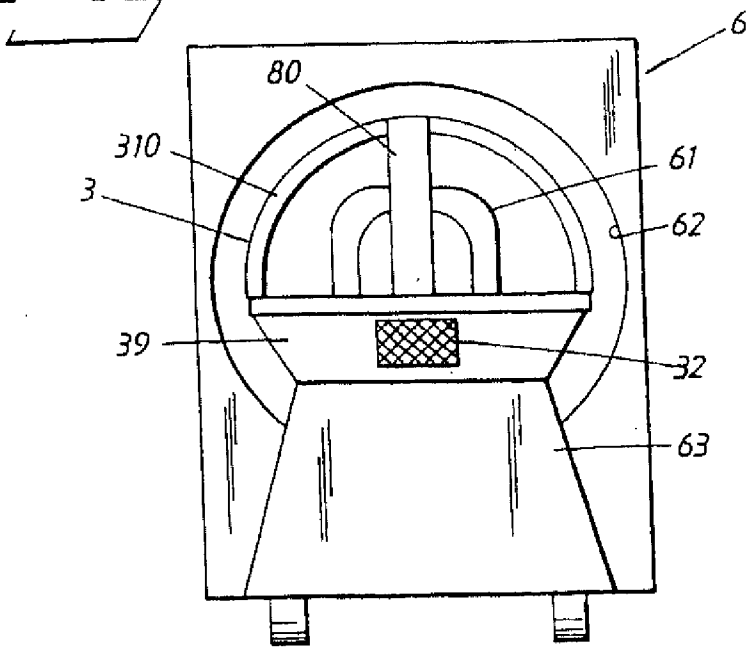

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Fig 3

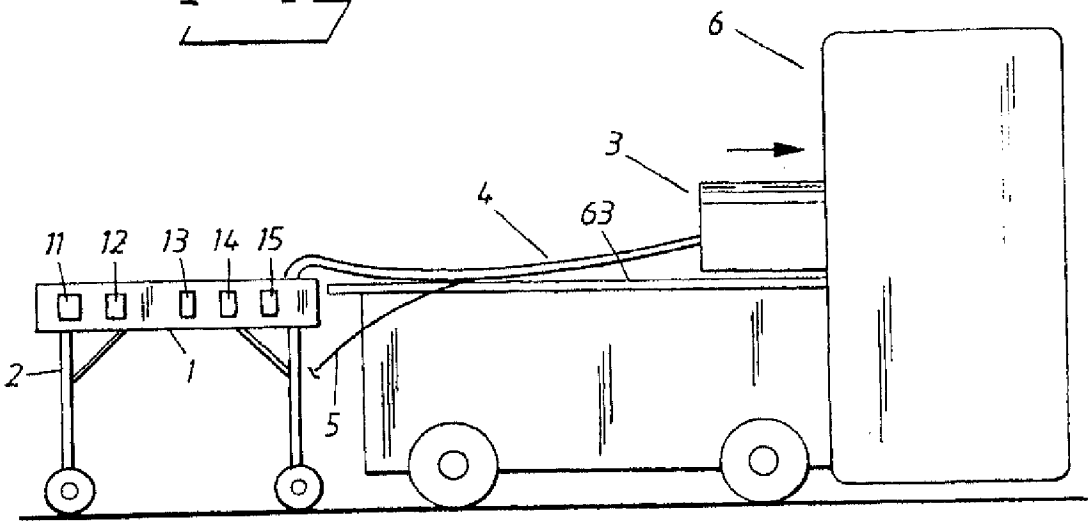

Fig 4

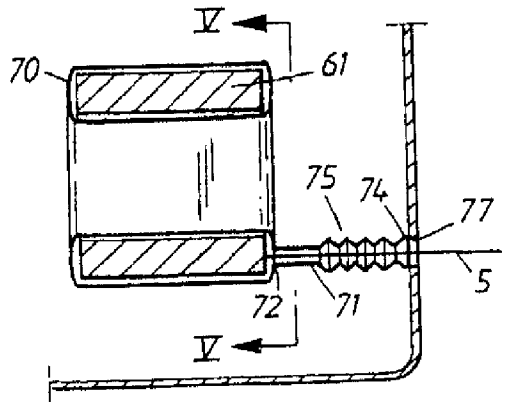

Fig 5